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The Processing of High Salinity Brines for Subsurface Injection

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THE PROCESSING OF HIGH SALINITY BRINES FOR SUBSURFACE INJECTION*

Ellen Raber** and Robert E. Thompson***

INTRODUCTION

The most significant environmental concerns in the development of geothermal/geopressure energy are aspects of reservoir pressure maintenance resulting from the withdrawal of enormous volumes of formation waters and the disposal of highly saline brines (up to 28% NaCl[1]). Therefore, large-scale utilization of these resources will require reinjection of spent brine effluents as the most environmentally acceptable method of disposal. We have recently been involved in evaluating different chemical pretreatments and filtration methods as a possible means of clarifying and improving the injectivity of hypersaline brines. This work involved extensive field tests at three Strategic Petroleum Reserve Sites (Bryan Mound in Texas, West Hackberry and Bayou Choctaw in Louisiana). Although the methodology and processing techniques used in this study can be applied elsewhere, the results are unique and specific to high-salinity brines (30-33% NaCl). These brines, which are low in silica, hydrogen sulfide, and other toxic trace metals, compare favorably with geothermal/ geopressured waters from Louisiana. Table 1 shows a comparison between analyses of high salinity brines. Studies done elsewhere include only treatment of undersaturated solutions with salinities up to 8% NaCl[2-3], although reactor-clarification has been suggested for the silica saturated hypersaline brines in the Imperial Valley, California.[4].

TEST OBJECTIVES AND PROCEDURES

The objective of this study was to determine processing requirements necessary to remove colloidal solids and produce an effluent which would not precipitate in the formation and impair injection well longevity. Initial field tests showed that direct injection without processing was not feasible, since wells plugged too rapidly. The clarification and processing methodology used in this study is shown in Figure 1.

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TABLE 1

CHEMICAL COMPARISON OF HIGH SALINITY BRINES (mg/l)

SPECIES	CAVERN	GEOPRESSURE(1)	GEOTHERMAL(2)
PH	6.5-7.0	6.1-7.5	5.84
SODIUM	122,227	84,600	42,400
CHLORIDE	188,533	168,600	121,000
SILICATE	N.D.	39-112	400-500
H_2S	< 1	< 1	10-30
SULFATE	710	1.4-691	89
BICARBONATE	300	170-2,000	--
IRON	< 1	.7-162	215
MAGNESIUM	13	10-1,500	81
CALCIUM	740	97-15,800	21,700
STRONTIUM	40	24-1,440	299
POTASSIUM	284	48-1,080	6,900
BARIUM	N.D.	2.2-370	150
BORON	< 2.0	15-69	300-400

(1) Kharaka et al. (1978) [1]

(2) Analyses from Salton Sea Geothermal Field (Magmamax #1)

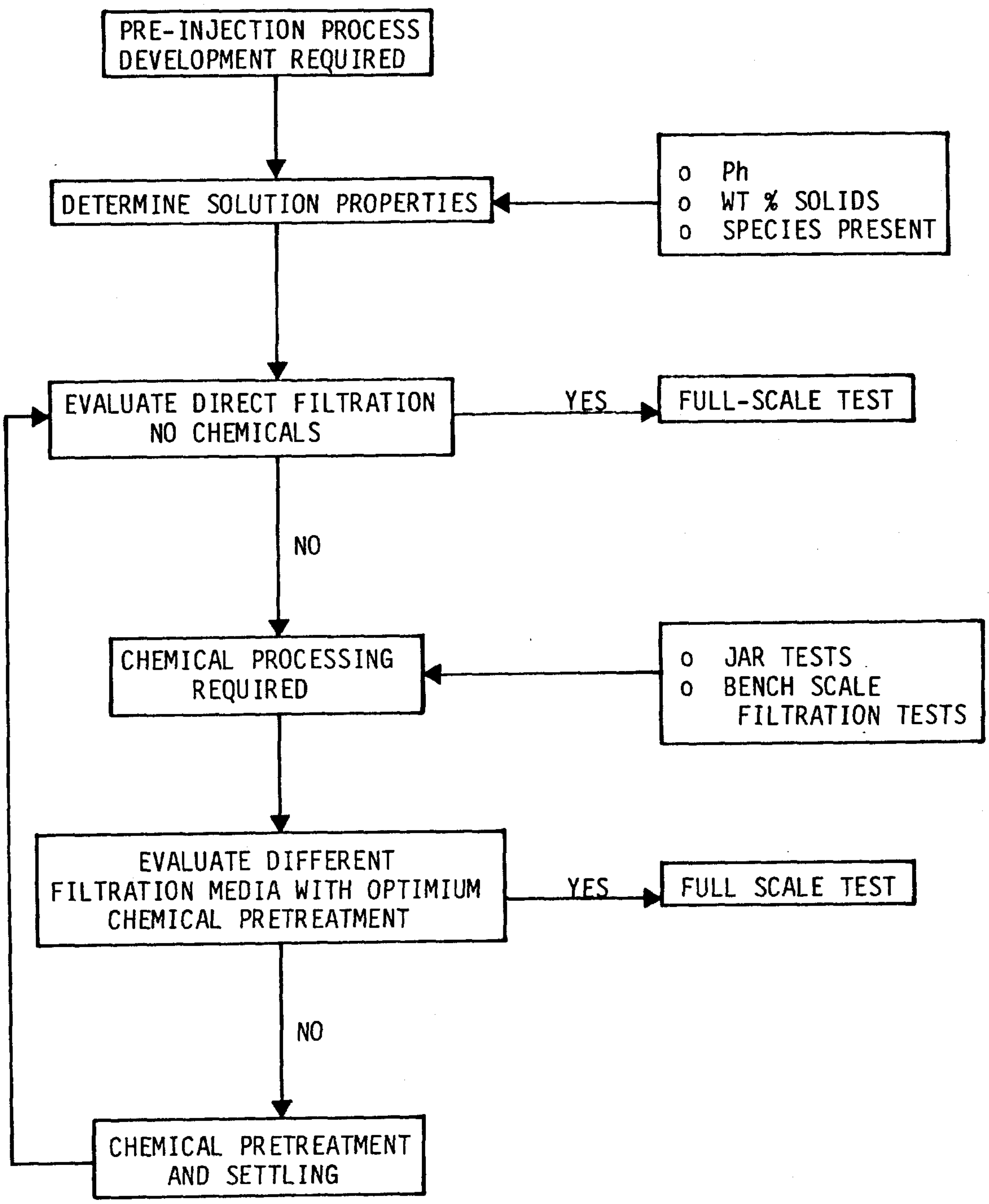

FIGURE 1. CLARIFICATION AND PROCESSING METHODOLOGY

Based upon the concentration of suspended solids and chemical composition of the brine, the main emphasis was placed on evaluating downflow granular media (combinations of coal, garnet and/or sand) filters. Six different media combinations were evaluated over the three sites, utilizing test data from 4 inch diameter pilot filters (Table 2). In addition, tests were conducted with one hollow fiber ultrafilter unit and two types of disposable cartridge filters. The test procedures employed in this study involved: (1) a bench-scale evaluation of pretreatment chemical aids, (2) pilot tests with and without chemical coagulants on downflow granular media filters, ultrafilters, and cartridge filters, and (3) particular techniques developed by LLL for the assessment of injectability utilizing filter membrane plugging factor tests.[5]

EVALUATION OF CHEMICAL PRETREATMENTS

One of the most important aspects of particulate removal is the use of coagulants/flocculants. These chemicals cause destabilization of the particle surface charge allowing particle agglomeration which enhances removal by filtration. Although inorganic and organic coagulants are used extensively in the wastewater industry, their effectiveness in hypersaline brines is not well established.

Over fifty inorganic salts and polymers were evaluated as coagulants/flocculants by a combination of jar testing and bench-scale filtration techniques. In summary, the results showed that high-molecular weight anionic polymers and aluminum salts (or aluminum salts plus nonionic polymers) were the most effective. Average turbidities were lowered from 10 to .20 NTU after addition of these chemicals. Anionic polymers have also been found to be effective coagulants in hypersaline geothermal brine.[4]

RESULTS FROM FILTRATION PILOT STUDIES

Filters were tested both with and without chemical additions to determine the most effective method of clarification. Cost assessments and filtration system comparisons are evaluated in Table 3. Filter performance was evaluated with regard to: (1) pressure loss vs. time (headloss), (2) effluent quality (turbidity), (3) length of filter cycle, (4) particle size distribution, and (5) injectability with respect to the permeability/porosity of the injection formation. However, due to varying degrees of contamination and minor differences in brine chemistry, no one filtration scheme can be recommended for all sites. The recommended granular media clarification systems for each individual site can be seen in Table 4.

The results obtained from these tests can be summarized as follows:

- Granular media direct filtration with no chemical treatment usually produces unacceptable quality effluent for injection although, occasionally, an acceptable quality effluent is produced. This suggests that the brine is sometimes at an electrolytic state in which

TABLE 2

CONSTRUCTION OF 4 " DIAMETER PILOT FILTERS

	Filter	Construction	Sites Tested
A	Single-media	12" silica sand	West Hackberry
A_1	Dual-media	12" garnet 18" anthracite coal	Bayou Choctaw
B	Dual-media	12" silica sand 18" anthracite coal	Bayou Choctaw and West Hackberry
C,D	Triple-media	3" garnet 9" silica sand 18" anthracite coal	Bayou Choctaw, West Hackberry, and Bryan Mound
E	Ultrafilter	Romacon hollow fiber cartridge; 3 in. dia. with 525-ml volume	Bayou Choctaw and Bryan Mound
F	Disposable cartridge	A,M,F, Cuno, 1.0 cartridge filters	Bayou Choctaw, West Hackberry, and Bryan Mound

Grain size silica sand = 0.45 - 0.6 mm
Garnet = 0.28 - 0.35 mm
Anthracite Coal = 1.0 - 1.1 m

TABLE 3

FILTRATION SYSTEM COMPARISONS
(BASED ON 150,000 BARRELS/DAY)

PARAMETER	GRANULAR FILTERS	ULTRAFILTRATION	DISPOSABLE CARTRIDGE FILTERS
ESTIMATED NUMBER OF ASSEMBLIES	24	25	4
TOTAL AREA REQUIRED FOR EQUIPMENT, FT^2	4,400	1,240	1,120
ESTIMATED CAPITAL COST OF ASSEMBLY*	$534,000	$1,898,000	$360,000
ADDITIONAL COSTS	YES - CHEMICALS	NO	NO
SOLIDS DISPOSAL**	3,000 GAL/DAY SLUDGE W/O ALUM AND 6,000 GAL/DAY SLUDGE W/ALUM	3,000 GAL/DAY SLUDGE	9600 CARTRIDGES PER DAY PLUS 3000 GAL/DAY SLUDGE

* BASED ON 1979 COSTS

** BASED ON 3% SOLIDS BY VOLUME

TABLE 4

RECOMMENDED GRANULAR MEDIA CLARIFICATION SYSTEMS FOR SPR SITES

Site Location	Chemical Additive	Concentration, mg/ℓ	Type	Media Construction
West Hackberry	ALUM $Al_2(SO_3)_4 \cdot 14H_2O$	3	Inorganic Al salt	Dual media (coal, sand) or triple media (coal, sand, garnet)
Bayou Choctaw[a]	Visco 3340	2-4	Anionic polymer	Triple media (coal, sand, garnet)
Bryan Mound[a]	ALUM + Cyfloc 4500	10 + 0.2	Inorganic Al salt + nonionic polymer	Triple media (coal, sand, garnet)

[a] Ultrafiltration without chemical aids was tested at these sites and was as effective and less sensitive to changing brine conditions.

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the diffuse layer of ions around the particle surface is sufficiently compressed, allowing some coagulation without the use of chemical additives.

- Granular media filtration with chemical pretreatment is an effective means for hypersaline brine clarification. Dual and triple media configurations produced a high-quality injectable effluent (turbidity < 0.20 NTU) with acceptable headloss rates and filter cycle times. High molecular weight polyacrylamide anionic polymers were the most effective coagulant aid, however, they do not seem to be effective when contamination from oil occurs. Under those conditions Alum ($Al_2(SO_4)_3 \cdot 14H_2O$) or Alum used in conjunction with high-molecular weight nonionic polyacrylamide polymers is more effective.

- Ultrafiltration produces an acceptable quality brine effluent without the necessity of chemical pretreatment (turbidity < .12 NTU), alleviating problems associated with chemical additives and changing brine conditions. However, more testing is necessary before a definite statement as to long-term effectiveness can be made. There is no industrial experience with ultrafilters having capacities of 150,000 to 200,000 bbl/d.

- Disposable Cartridge Filters effectively reduce suspended solids without the use of chemical aids. However, they plug too rapidly and frequent renewal would not be practical for the treatment of large quantities of brine.

- Postprecipitation tendencies of processed brine effluents were evaluated by incubation tests and are not a problem. However, brine effluent should be evaluated at each site once optimum clarification methodology has been determined.

- Residual polymer in brine effluent has a large effect on .45 and 1.0 micron plugging factor injectivity tests. Laboratory experiments confirmed that in highly electrolytic solutions there is a definitive relationship between residual polymer concentration, molecular weight and plugging factor. This must be taken into consideration in any large-scale system design.

REFERENCES

1. Kharaka, Y. K., Brown, P. M., and Carothers, W. W., "Chemistry of Waters in the Geopressured Zone from Coastal Louisiana--Implications for Geothermal Development", Geothermal Resources Council, Transactions, Vol. 1, 371 (1978).

2. Jordon, C. A., Edmondson, T. A., and Jeffries-Harris, M. J., "The Bay Marchand Pressure Maintenance Project-Unique Challenges of an Offshore Seawater Injection System", Journ. Pet. Tech.,389 (1979).

3. Farley, J. T. and Redline, D. G., "Evaluation of Flood Water Quality in the West Montalvo Field", Journ. Pet. Tech., 683 (1968).

4. Quong, R., Schoepflin, F., Stout, N. D., Tardiff, G. E., and McLain, F. R., "Processing of Geothermal Brine Effluent for Injection", Geothermal Resources Council, Transactions, Vol. 2, 551 (1978).

5. Netherton, R. and Owen, L. B., "Apparatus for the Field Evaluation of Geothermal Effluent Injection", Geothermal Resources Council, Transactions, Vol. 2, 487 (1978).

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